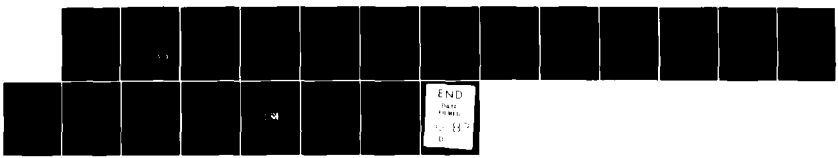
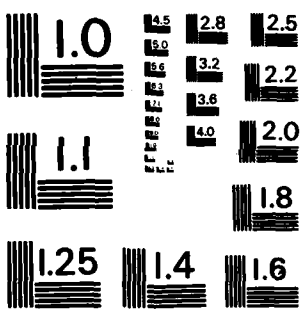
AD-A133 505 QUALITATIVE ASSESSMENT OF THE IGNITION OF HIGHLY FLAMMABLE FUELS BY PRIMARY EXPLOSIVES(U) MATERIALS RESEARCH LABS ASCOT VALE (AUSTRALIA) 1/1

UNCLASSIFIED P P ELISCHER ET AL. JUN 83 MRL-R-889 F/G 21/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

(12)

MRL-R-889

AR-003-302

AD-A133 505

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

MATERIALS RESEARCH LABORATORIES

MELBOURNE, VICTORIA

REPORT

MRL-R-889

QUALITATIVE ASSESSMENT OF THE IGNITION OF HIGHLY FLAMMABLE FUELS BY PRIMARY EXPLOSIVES

P.P. Elischer and Leo de Yong

Approved for Public Release

DEPARTMENT OF DEFENCE

MATERIALS RESEARCH LABORATORIES

REPORT

MRL-R-889

QUALITATIVE ASSESSMENT OF THE IGNITION OF HIGHLY FLAMMABLE FUELS BY PRIMARY EXPLOSIVES

P.P. Elischer and Leo de Yong

ABSTRACT

An assessment of the ignition of fuel/air mixtures and of fabrics soaked with different fuels (ethanol, n-hexane and diethyl ether) by primary explosives has been carried out.

POSTAL ADDRESS: Director, Materials Research Laboratories
P.O. Box 50, Ascot Vale, Victoria 3032, Australia

SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED

DOCUMENT CONTROL DATA SHEET

REPORT NO.	AR NO.	REPORT SECURITY CLASSIFICATION
MRL-R-889	AR-003-302	UNCLASSIFIED

TITLE
QUALITATIVE ASSESSMENT OF THE IGNITION OF HIGHLY FLAMMABLE FUELS BY PRIMARY EXPLOSIVES

AUTHOR(S)
P.P. Elischer
Leo De Yong

CORPORATE AUTHOR
Materials Research Laboratories
P.O. Box 50,
Ascot Vale, Victoria 3032

REPORT DATE	TASK NO.	SPONSOR
JUNE 1983	ARM 82/131	ARMY

CLASSIFICATION/LIMITATION REVIEW DATE

CLASSIFICATION/RELEASE AUTHORITY
Superintendent, MRL Physical Chemistry Division

SECONDARY DISTRIBUTION

Approved for Public Release

ANNOUNCEMENT

Announcement of this Report is unlimited

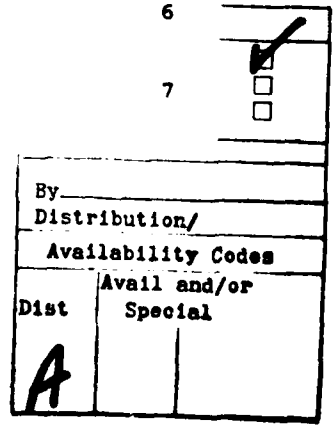
KEYWORDS
Ignition
Flammability
Igniters
Primers (Explosives)
Fuels
Primary Explosives

COSATI GROUPS 2102 1901

ABSTRACT

An assessment of the ignition of fuel/air mixtures and of fabrics soaked with different fuels (ethanol, n-hexane and diethyl ether) by primary explosives has been carried out.

CONTENTS



QUALITATIVE ASSESSMENT OF THE IGNITION OF HIGHLY FLAMMABLE FUELS BY PRIMARY EXPLOSIVES

1. INTRODUCTION

A search of the literature revealed that there are no standard tests which relate to the ignitability of flammable environments by primary explosives. Situations arise, both in civilian and military practice, where this information is either necessary or highly desirable.

In this report, the authors sought to establish a suitable test for assessing the ignitability of either fuel/air mixtures (vapour state ignition) or fuel-soaked woven fabrics (liquid-vapour state ignition) in the presence of either initiating primary explosives, a photoflash pyrotechnic composition or an electric fusehead.

2. RESULTS AND DISCUSSION

2.1 Flammable Environments

The limits of flammability, flash point and auto ignition temperature of several common organic solvents are given in Table 1.

As the most likely environment in which fuel-air mixtures are to be encountered in practice are those involving organic solvents or petroleum based fuels, it was decided to study the flammability of ethyl alcohol, diethyl ether and n-hexane (as a model for petroleum fuels).

Brown [1] has reported that a very small amount of a volatile contaminant in a relatively non flammable fuel may make it flammable, and Affens [2] has shown that small amounts of volatile n-alkanes present in a relatively non inflammable mixture of n-alkanes will yield a flammable mixture. As petrol contains predominantly C_5-C_{10} n-alkanes, results obtained using n-hexane (C_6) can probably be applied to petroleum.

2.2 *Ignition of Flammable Environments by Primary Explosives*

The study of ignition of flammable environments by primary explosives concentrated on two areas:

1. Ignition of fuel soaked fabrics
2. Ignition of fuel/air mixtures.

Depending on the nature of the ignition source and the fuel/air ratio, combustion of a fuel/air mixture can occur either by deflagration or detonation. Hooper [3] has reported that the mass of high explosive (tetryl) required to cause detonation in fuel/air mixtures ranged from less than 1 g (acetylene/air) to 10 kg (methane/air) for gas volumes up to 2 m^3. It is considered that the possibility of a fuel/air mixture detonating when exposed to the output from approximately 200 mg of primary explosive is remote.

2.2.1 *Ignition of fuel soaked fabrics using primary explosive*

These tests were carried out to screen the primary explosives and to ascertain whether they would ignite material soaked with fuel. Two series of tests were carried out:-

(i) using a loose woven fabric (cheesecloth), and

(ii) using a tight woven fabric (nylon carpet).

Cheesecloth was chosen because its open weave would expose a large surface area to the output of the explosive and carpet was chosen because it is a common floor covering, representative of modern tight woven fabrics.

In all cases, 200 mg of primary explosive was used.

2.2.1.1 *Loose woven fabrics*

Selected primary explosives were confined in metal, perspex or bakelite tubes and fired onto hexane soaked cheesecloth using different igniter systems. Igniter tubes, filled with Photoflash Composition, MRL(X)206, were used as controls. These tubes consistently ignited the hexane-soaked fabric.

The results listed in Tables 2, 3 & 4 indicate that the ignition of hexane soaked cheesecloth depends on the ignition system, the primary explosive and on the igniter tube.

To test this, experiments were carried out using metal tubes (brass and aluminium) in place of the bakelite and perspex tubes (Table 4). Unlike

the tests summarized in Tables 2 & 3, the hexane soaked cheesecloth did not ignite. The ignition of the cheesecloth was attributed to the perspex or bakelite tubes bursting and exposing the flammable atmosphere to hot perspex or bakelite particles. The metal tubes did not burst nor did the force of the explosion significantly affect their physical dimensions.

2.2.1.2 Tight woven fabrics

A number of explosive units manufactured from metal tubing were fired over tightly woven fabric (carpet) soaked in ethanol. Ethanol was chosen as the fuel because of its wider flammability range compared to n-hexane. The results are summarised in Table 5.

Although there was some carbonaceous residue remaining on the carpet, the ethanol and carpet did not ignite. Electric fuseheads, used as controls, did ignite the ethanol which caused the carpet to burn.

2.2.2 Ignition of fuel/air mixtures

Investigations were also carried out to determine whether primary explosives filled into brass or aluminium tubes would ignite fuel/air mixtures. Metal tubes were filled with 200-400 mg of lead styphnate, 200 mg of lead dinitro-resorcinate or 200 mg of tetracene and ignited using nichrome bridgewires.

Three different fuels were assessed: ethanol, n-hexane and diethyl ether. These fuels have a range of auto-ignition temperatures and flammability limits (Table 1) corresponding to a range of flammabilities. Stoichiometric volumes (V_s) and volumes corresponding to the middle of the flammable range (V_m) were used. Controls to check ignition of the fuel/air mixture were fired into the test vessel prior to the commencement of the test.

The results summarized in Table 6 show that lead styphnate, tetracene and lead dinitro-resorcinate in the tubes used, did not ignite the fuel/air mixtures investigated.

3. CONCLUSION

For the arrangements examined, the primary explosives when confined in metal tubes did not ignite the fuel soaked fabrics nor the fuel/air mixtures. However, with perspex or bakelite tubes, ignition occurred possibly due to break up of the tube.

Examination of the reasons why the primary explosives did not ignite the flammable environments is complex and depends strongly on diffusive and chemical parameters such as intensity and duration of heat source and properties of the flammable mixture such as thermal conductivity and temperature of ignition. These parameters were not examined in this report

as only a qualitative assessment of specific primary explosive arrangements was required.

4. EXPERIMENTAL

4.1 General

The hydrocarbon fuels, the cheesecloth and the carpet used for the flammability investigations were all commercially available. n-Hexane diethyl ether and ethanol were analytical grade reagents. The primary explosives used in the investigation are listed below:-

basic lead azide
lead azide
lead styphnate
barium styphnate
potassium picrate
lead dinitro-resorcinate (LDNR)
and tetracene

They were prepared at the Materials Research Laboratories using established techniques. The Photoflash Composition, MRL (X) 206, was prepared at the *Materials Research* Laboratories using 40% magnesium, 59% potassium perchlorate and 1% acroid resin.

Electric Fuseheads

These were the standard ICI Vulcan Type A matchheads which contain a 0.9-1.6 Ω resistance nichrome bridgewire, 0.041 mm diameter.

Experimental Bridgewire Devices

These devices were manufactured at MRL (Fig. 1). They were fabricated from plastic, which was moulded around two phosphor bronze terminals. Platinum wire (0.04 mm diameter, 0.2 Ω resistance) or nichrome wire (0.015 mm diameter, 12-20 Ω resistance) was used as the bridgewire which was spot welded to the terminals.

4.2 *Manufacture of Tubes Containing Primary Explosives*

4.2.1 *Bakelized paper tubes*

These tubes were constructed using commercially available bakelized paper (9 mm OD, 7.2 mm ID, 30 mm L). They were fitted with fuseheads held in place with a rubber grummet and epoxy resin. The explosive compositions were loose filled into the tube and lightly consolidated with a 4 mm cork disc and a fillet of epoxy resin.

4.2.2 *Perspex tubes*

These tubes were prepared using perspex (12.5 mm OD, 4.1 mm ID, 15 mm L). Platinum or nichrome bridgewire devices were fitted to the tube using Eastman 910 adhesive. The primary explosive was pressed into the tubes using an Altor press and 35 kg dead load. These tubes were not sealed.

4.2.3 *Metal tubes*

The metal tubes were constructed from aluminium (15 mm OD, 9 mm ID, 15 mm L) or brass (9.5 mm OD, 7.2 mm ID, 14 mm L). They were fitted with bridgewire devices held in place with Eastman 910 adhesive. The explosive was loose filled into the tubes and lightly consolidated with a cork (4 mm thick) or cardboard disc (2 mm thick) and a fillet of epoxy resin (Fig. 1).

4.3 *Ignition of Hydrocarbon Fuel/Air Mixtures*

A test to assess the ignition characteristics of various fuel/air mixtures when exposed to different explosive stimuli was developed. The test apparatus consisted of a 20 litre metal container fitted with an air driven stirrer which was permanently attached through the side near the bottom. A plastic sheet was held securely over the top of the container with a large metal hose clip. The explosive tube or electric fusehead was inserted through a hole in the plastic so that it was suspended in the middle of the container. Hydrocarbon fuel was injected through the plastic using a syringe. Both holes were sealed with adhesive tape. The volume of fuel used for the tests was either a stoichiometric amount (Vs) or an amount corresponding to the middle of the flammability range (Vm). The relevant figures to calculate those volumes were obtained from the literature (4 & 5). A homogeneous fuel/air mixture was obtained by mixing the vapour for five minutes using the air driven stirrer. This was then turned off and the test units fired using a capacitor discharge firing box. The mixing of diethyl ether and n-hexane was carried out at ambient temperature. However, for ethanol, due to its lower volatility at ambient temperature, a homogeneous mixture was obtained by pre-heating the container to approx 30°C.

A firing was deemed successful when the fuel/air mixture did not ignite. Conversely ignition of the fuel/air mixture indicated by a fire ball, was classed as a failure. After each successful firing, the remaining

fuel was ignited using an electric fusehead.

4.4 Flammability of Loose Woven Fabric Saturated with Fuel

Cheesecloth material was cut into strips (63 mm x 200 mm), placed into an uncovered 20 litre container and thoroughly soaked with about 50 cm^3 of fuel. The primary explosive tubes or electric fuseheads were suspended 100 mm above the material and initiated. Again the firing was successful if the fuel soaked material did not ignite. If the cheesecloth ignited and was badly charred, it was replaced for subsequent tests. The cheesecloth was also replaced when the flammability characteristics of different hydrocarbon fuels were investigated.

4.5 Flammability of Tight Woven Fabric Saturated with Fuel

A sample of commercial nylon carpet (approximately 0.6 m^2) containing no fire retardant material, was saturated with 50 cm^3 of liquid fuel. The primary explosive tubes were orientated at different angles to the carpet and fired electrically. The following configurations were used:

(a) resting on the carpet, facing down at right angles to the plane of the carpet;

(b) resting on the carpet parallel to the plane of the carpet;

(c) held approximately 20 mm above the carpet facing down at right angles to the carpet.

Again a firing was successful if the carpet did not ignite.

5. ACKNOWLEDGEMENT

The helpful discussions and advice from Dr J. McRae on flammability of solvents is acknowledged.

6. REFERENCES

1. Brown, N.D., "An Investigation of the Flammability Characteristics of Diesel Fuel", Admirality Oil Laboratory (Surrey), Technical Memorandum No. 49, February 1971.

2. Affens, W.A., "The Flammability Properties of Hydrocarbon Fuels, Part 2. The Importance of Volatile Components at Low Concentrations on the Flammability of Liquid Fuels", Naval Research Laboratory (Washington), Report No. 6578, July 1967.

3. Hooper, G., "An Experimental Study of the Sensitiveness of Unconfined Hydrocarbon Air Mixtures to Direct Detonative Initiation", Propellants and Rocket Motor Establishment, (Essex), Technical Report No. 44, December 1977.

4. Hilado, C.J., "Flammability Test Methods Handbook", Technomic Publishing Co. Inc.

5. "Explosive Gas Atmospheres", Australian Standard AS 2430, Pt 2, 1981.

T A B L E 1

LIMITS OF FLAMMABILITY OF GASES AND VAPOURS IN AIR [4,5]

Component	Boiling Point at 1 at. (°C)	Vapour Density compared with air (air = 1)	Flash Point (°C)	Auto Ignition Temperature (°C)	Flammability Limits in air	
					Upper Vol %	Lower Vol %
n-Butane	- 1	2.05	- 60	405	8.44	1.8
n-Pentane	36	2.48	< - 20	258	7.8	1.4
n-Hexane	69	2.79	- 21	223	7.4	1.2
n-Heptane	98	3.46	- 4	223	6.7	1.05
n-Octane	126	-	-	220	-	0.95
n-Nonane	151	4.43	30	206	5.6	0.85
n-Decane	174	-	-	208	5.6	0.75
Ethanol	78	1.59	12	365	19.0	3.3
Diethyl ether	34.5	2.55	< - 20	160	36.0	1.9
Dimethyl ether	- 25	1.59	-	350	27.0	3.4

TABLE 2

IGNITION OF HEXANE SOAKED CHEESECLOTH USING ELECTRIC FUSEHEADS IN BAKELITE TUBES

Ignition System	Primary Explosive	Flammability
Electric Fusehead in Bakelite Tubes	Basic Lead Azide	✓
" "	Lead Styphnate	✓
" "	LDNR	✓
" "	Barium Styphnate	✓
" "	Flash Composition	✓
" "	Potassium Picrate	✓

TABLE 3

IGNITION OF HEXANE SOAKED CHEESECLOTH USING BRIDGEWIRES IN PERSPEX TUBES

Ignition System	Primary Explosive	Flammability
Platinum Bridgewire in Perspex Tubes	Potassium Picrate	✓
" "	Basic Lead Azide	X
" "	Lead Azide	X
" "	Lead Styphnate	✓
Nichrome Bridgewire in Perspex Tubes	Lead Styphnate	✓

✓ denotes ignition of fuel soaked rags

X denotes no ignition of fuel soaked rags

TABLE 4

IGNITION OF HEXANE SOAKED CHEESECLOTH USING ALUMINIUM AND BRASS TUBES

Ignition System	Primary Explosive	Flammability
Nichrome Bridgewire in Aluminium Tube	Potassium Picrate	X
" " "	LDNR	X
" " "	Barium Styphnate	X
" " "	Tetracene	X
" " "	200 mg Lead Styphnate	X
" " "	400 mg Lead Styphnate	X
" " "	600 mg Lead Styhpnate	X
Nichrome Bridgewire in Brass Tube	Tetracene	X
" "	Lead Styphnate	X

✓ denotes ignition of fuel soaked rags

X denotes no ignition of fuel soaked rags

TABLE 5

IGNITION OF ETHANOL SOAKED CARPET

Primary Explosive	Position	Results
Lead Styphnate	Resting on carpet, facing onto carpet	No ignition of carpet, charring
" "	Held down approx 20 mm from carpet	" "
" "	Held down facing along surface of carpet	" "
LDNR	Resting on carpet, facing onto carpet	" "
"	Held down approx 20 mm from carpet	" "
"	Held down facing along surface of carpet	" "
Tetracene	Held down approx 20 mm from surface of carpet	No ignition, no charring
"	Resting on carpet facing along surface of carpet	" "
Electric Fusehead	Held down approx 20 mm from surface of carpet	Fuel ignited and carpet burnt
" "	Resting on carpet facing along surface of carpet	" "
Flash Composition	Held down approx 20 mm from surface of carpet	No ignition, charring, hole in carpet

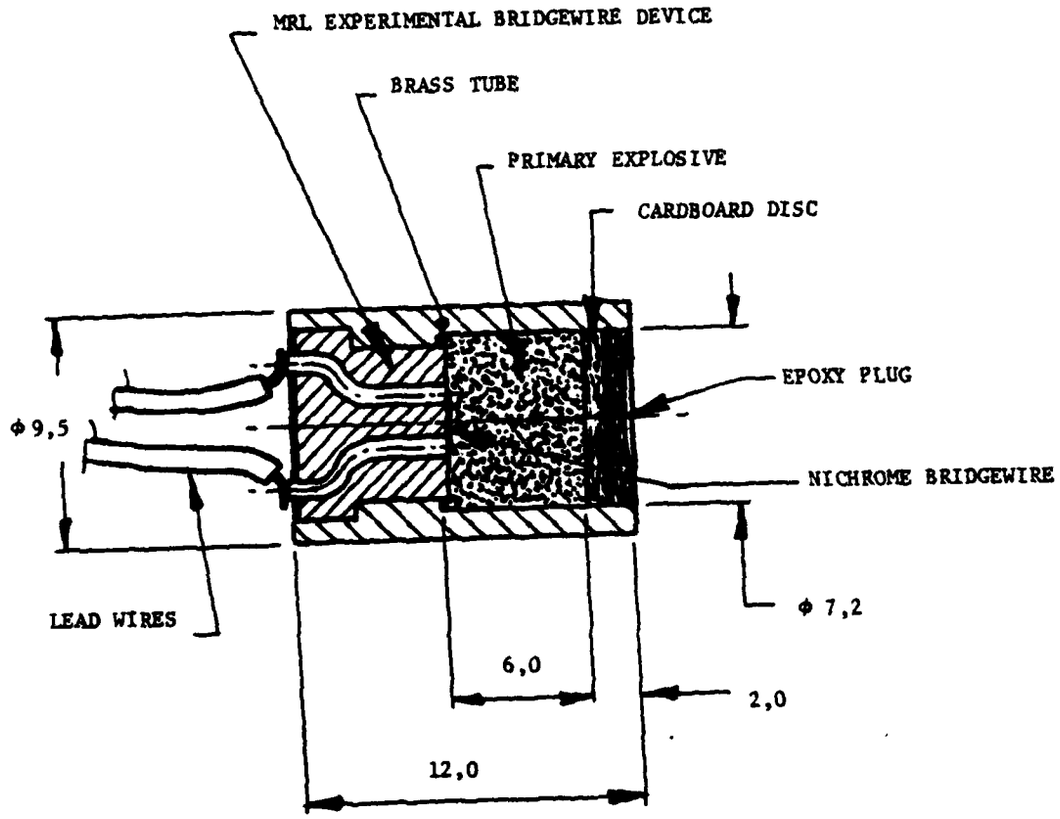
TABLE 6

IGNITION OF FUEL/AIR MIXTURES USING BRIDGEWIRES AND METAL TUBING

Primary Explosive	Fuel	Volume	Flammability
Electric Fusehead	Hexane	Vs & Vm	✓
" "	Ethanol	Vs	✓
" "	Ether	Vs	✓
200 mg Lead Styphnate (Aluminium Tube)	Hexane	Vs & Vm	X
" " " " "	Ethanol	Vm	X
" " " " "	Ether	Vs & Vm	X
300 mg Lead Styphnate " "	Hexane	Vm	X
400 mg Lead Styhpnate " "	Hexane	Vm	X
200 mg LDNR " "	Hexane	Vs & Vm	X
" " " "	Ethanol	Vm	X
" " " "	Ether	Vs & Vm	X
200 mg Tetracene (Aluminium tube)	Hexane	Vs	X
" " " "	Ethanol	Vs	X
" " " "	Ether	Vs & Vm	X
200 mg Tetracene (Brass tube)	Ether	Vs & Vm	X

✓ denotes ignition of fuel/air system

X denotes no ignition of fuel/air system



(DIMENSIONS IN mm)

FIG. 1 EXPLOSIVE TUBE

(MRL-R-889)

DISTRIBUTION LIST

MATERIALS RESEARCH LABORATORIES

Director
Superintendent, Physical Chemistry Division
Mr R. Bird
Mr P. Ramsay
Dr J. Eadie
Library (2 copies)
P.P. Elischer
L. de Yong

DEPARTMENT OF DEFENCE

Chief Defence Scientist/Deputy Chief Defence Scientist/ (1 copy)
Controller, Projects and Analytical Studies/
Superintendent, Science and Technology Programme
Army Scientific Adviser
Air Force Scientific Adviser
Navy Scientific Adviser
Officer-in-Charge, Document Exchange Centre (17 copies)
Technical Reports Centre, Defence Central Library
Central Office, Directorate of Quality Assurance - Air Force
Deputy Director Scientific and Technical Intelligence, Joint
Intelligence Organisation
Librarian, Bridges Library
Librarian, Engineering Development Establishment
Defence Science Representative, (Summary Sheets Only)
Australia High Commission, London
Counsellor Defence Science, Washington, D.C. (Summary Sheets Only)

DEPARTMENT OF DEFENCE SUPPORT

Deputy Secretary, DDS
Librarian, (Through Officer-in-Charge), Materials Testing
Laboratories, Alexandria, NSW
Senior Librarian, Aeronautical Research Laboratories
Senior Librarian, Defence Research Centre, Salisbury, SA
Head of Staff, British Defence Research & Supply Staff (Aust.)

OTHER FEDERAL AND STATE DEPARTMENTS AND INSTRUMENTALITIES

NASA Canberra Office, Woden, ACT
The Chief Librarian, Central Library, CSIRO
Library, Australian Atomic Energy Commission Research Establishment

(MRL-R-889)

DISTRIBUTION LIST
(Continued)

MISCELLANEOUS - AUSTRALIA

Librarian, State Library of NSW, Sydney NSW
University of Tasmania, Morris Miller Library, Hobart, Tas.

MISCELLANEOUS - OVERSEAS

Library - Exchange Desk, National Bureau of Standards, USA
UK/USA/CAN/NZ ABCA Armies Standardisation Representative (4 copies)
The Director, Defence Scientific Information & Documentation Centre, India
Military, Naval and Air Adviser, High Commission of India, Canberra
Director, Defence Research Centre, Kuala Lumpur, Malaysia
Exchange Section, British Library, UK
Periodicals Recording Section, Science Reference Library, British Library, UK
Library, Chemical Abstracts Service
INSPEC: Acquisition Section, Institute of Electrical Engineers, UK
Engineering Societies Library, USA
Aeromedical Library, Brooks Air Force Base, Texas, USA
Ann Germany Documents Librarian, The Centre for Research Libraries, Chicago, Ill.
Defense Attache, Australian Embassy, Bangkok, Thailand (Att. D. Pender)

END

DATE
FILMED

10 83

DT